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Article

Enhancement of the growth and yield of wheat in coastal saline areas through organic and inorganic amendments

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Abstract: Salinity is a major limiting factor reducing crop yields in coastal areas of Bangladesh. The main objective of this study was to mitigate the adverse effects of soil salinity on wheat by organic and inorganic amendments. The field experiment was conducted at BRRI station, Sonagazi, Feni. Wheat cv. BARI Gom-23 was used as a test crop. There were thirteen treatment combinations consisting of control, farmyard manure (FYM) (5 t ha^{-1}), FYM (10 t ha^{-1}), compost (10 t ha^{-1}), compost (20 t ha^{-1}), gypsum (50% GR), gypsum (100% GR), K_2SO_4 (100 kg ha^{-1}), K_2SO_4 (200 kg ha^{-1}), FYM (5 t ha^{-1}) + gypsum (50% GR), FYM (5 t ha^{-1}) + K_2SO_4 (100 kg ha^{-1}), compost (10 t ha^{-1}) + gypsum (50% GR), compost (10 t ha^{-1}) + K_2SO_4 (100 kg ha^{-1}). FYM and compost were added to the soils during final land preparation. Gypsum and sulphate of potash were applied in two splits as per treatments. Nitrogen, phosphorous, zinc and boron fertilizers were applied as basal doses. The experiments were laid out in a randomized complete block design with three replications. Soil salinity caused a reduction in growth and yield of wheat. Soil amendments with organic or inorganic fertilizers improved growth and yield of wheat under soil salinity. Combined application of organic and inorganic fertilizers showed higher yields of wheat than that of alone during salinity conditions. Both organic and inorganic fertilizers increased nutrient uptake and K^+/Na^+ ratio in wheat during salinity condition. Therefore, the present study suggests that wheat production might be feasible in coastal areas of southern Bangladesh through organic and inorganic amendments of saline soils.

Keywords: crop yield; wheat; coastal saline areas; organic and inorganic amendments

1. Introduction

Wheat (*Triticum aestivum* L.) is the most important cereal crop and it ranks first both in acreage and production in the world (FAO, 2008). It has been established as the second most important staple food crop after rice in Bangladesh. Bangladesh produces 1302998 metric tons of wheat per annum in 1061602 acres of land (BBS, 2014). About one-third of the total population in the world lives on wheat grain consumption. Wheat production should be increased to meet the demand of the escalating population of Bangladesh, where an individual requires 454 g cereal food per day (BARI, 2004). It supplies carbohydrate, protein, minerals and vitamins and more prefers to rice for its higher seed protein content.

Soil salinity is a major concern to agriculture all over the world because it affects almost all plant functions. Approximately 7% of the world's land area, 20% of the world's cultivated land and nearly half of the irrigated land are affected by soil salinity (FAO, 2008). Moreover, soil salinization is becoming increasingly detrimental to agriculture due to irrigation (Flowers and Yeo, 1995). In view of another projection, 2.1% of the global dry land agriculture is affected by salinity (FAO, 2008).

Agriculture is the most important sector of Bangladesh's economy. Usually 30-50% yield losses occur depending on the level of soil salinity. Over 30% of the cultivable area of Bangladesh lies in the coastal and offshore zones. Out of 2.86 million hectares of coastal and offshore lands, about 1.06 million hectares are affected by varying degrees of salinity (SRDI, 2010). The area under salinity is increasing with time (from 0.83 m ha to 1.06 m ha in 36 years (SRDI, 2010) due to rise in sea water level with increased global temperature. Increased soil salinity due to climate change would significantly reduce food grain production.

Salinity is a major abiotic environmental stress to crop production. Plants are frequently exposed to various abiotic stresses during its growth and development. Salinity drastically affects crop growth and poses a major threat to agricultural productivity worldwide. In general, high level of salt in soil causes imbalance in osmotic potential, ionic equilibrium and nutrient uptake (Munns, 2002). Sodium (Na^+) is the predominant soluble cation in most saline soil and water. A high level of Na^+ is toxic to plants because it disturbs cytoplasmic K^+/Na^+ homeostasis. A low ratio of Na^+ to K^+ in the cytosol is essential for normal cellular functions of plants. Na^+ competes with K^+ uptake, causing an increase in Na^+ to K^+ ratio in the cytosol under salt stress, resulting in accumulation of toxic levels of Na^+ and insufficient K^+ concentrations for enzymatic reactions and osmotic adjustment (Zhu, 2002, 2003). The deficiency of K^+ initially leads to chlorosis and then causes necrosis (Gopal *et al.*, 2003). High external Na^+ displaces calcium (Ca^{2+}) from the plasma membrane, leading to increased membrane leakage and K^+ efflux (Cramer *et al.*, 1985) and increased Na^+ influx (Cramer *et al.*, 1987).

Several strategies have been proposed to alleviate the degree of cellular damage caused by abiotic stress and to improve plant salt tolerance. Appropriate management strategies and techniques with suitable genotypes having higher yield potential contribute to the improvement of crop production in the coastal areas of Bangladesh. Both organic and inorganic amendments are found to be effective in the amelioration of saline soils. Various organic amendments such as FYM, compost, poultry manure and mulch can be used for the amelioration of saline soils. Removal of exchangeable sodium necessitates application of inorganic amendments to remove sodium from the exchangeable site of soil. Gypsum is commonly used in reclamation of saline, saline-sodic and sodic soils. Salt tolerance is directly associated with K contents because of its involvement in osmotic regulation and competition with Na. Application of potash fertilizer reduces the adverse effects of salinity in sugarcane.

Soil salinity management in salt-affected coastal areas of Bangladesh to increase wheat crop production, is a great concern in recent days and for this reason emphasis has been given on this issue. In this regard application of organic and inorganic amendments would be one of the options to improve the salinity on wheat growth and productivity. The objectives of this study were to investigate the effect of organic and inorganic amendments on the growth and yield of wheat, K^+/Na^+ ratio and nutrient uptake under salinity condition.

2. Materials and Methods

2.1. Experimental site and soils

The field experiment was conducted at BRRI regional station, Sonagazi, Feni and the site also belongs to the Agro-ecological Zone of the Young Meghna Estuarine Floodplain (AEZ 18) to investigate the mitigation of soil salinity in wheat through organic and inorganic amendments. The experimental area is under the sub-tropical climate that is characterized by less rainfall associated with moderately low temperature during the rabi season (October-March). The experiment was laid out in a randomized complete block design with three replications. Soil samples were collected from 0-30 cm depth to determine gypsum requirements (GR) and soil properties of the experimental plots. The soils were silt loam having pH 6.8, EC 4.09 dS m^{-1}, exchangeable Na 1.238 me/100 g soil and CEC 23.35 me/100 g soil.

2.2. Plant materials and treatments

Wheat cv. BARI Gom-23 was used as a test crop with 13 treatment combinations viz. control, FYM (5 t ha^{-1}), FYM (10 t ha^{-1}), compost (10 t ha^{-1}), compost (20 t ha^{-1}), gypsum (50% GR), gypsum (100% GR), K_2SO_4 (100 kg ha^{-1}), K_2SO_4 (200 kg ha^{-1}), FYM (5 t ha^{-1}) + gypsum (50% GR), FYM (5 t ha^{-1}) + K_2SO_4 (100 kg ha^{-1}), compost (10 t ha^{-1}) + gypsum (50% GR), compost (10 t ha^{-1}) + K_2SO_4 (100 kg ha^{-1}).

Wheat seeds were sown in the experimental field, and then seeds were covered by soil. FYM, compost, phosphorous, zinc and boron fertilizers were added to the soils during final land preparation. Gypsum and sulphate of potash were applied in two splits as per treatments. Nitrogen was applied in three splits to all the experimental plots. Irrigation and other management practices were performed as and when required. The crop was harvested at full maturity. Grain and straw yields and plant parameters were recorded.

2.3. Chemical analysis of plant samples

The representative grain and straw samples were dried in an oven at 65^0C for about 24 hours before they were ground by a grinding machine. The prepared samples were stored in paper bags and finally kept into desiccators until analysis. The N, P, K, S and Na contents from grain and straw samples were determined following standard method as described by Khanam *et al*. (2001).

2.4. Statistical analysis

Data were analyzed statistically using analysis of variance with the help of software package MSTAT-C. The significant differences between mean values were compared by Duncan's Multiple Range Test. Differences at $P \leq 0.05$ were considered significant.

3. Results and Discussion

3.1. Growth and yield components of wheat

Salinity caused a significant decrease in plant height of BARI Gom-23 (Table 1). Application of gypsum (100% GR) significantly increased the plant height of BARI Gom-23 under salinity condition. It is important to note that organic and inorganic amendments with FYM and gypsum resulted in a significant increase in plant height of wheat. Salinity decreased in spike length of BARI Gom-23 (Table 1). Combined amendments with FYM (5 t ha^{-1}) and K_2SO_4 (100 kg ha^{-1}) showed higher spike length of BARI Gom-23 than other amendments. Salinity caused a significant reduction in number of spikelets spike^{-1} of wheat (Table 1). Organic and inorganic amendments contributed to the remarkable numbers of spikelets spike^{-1} of wheat under salinity. Application of FYM (5 t ha^{-1}) or compost (10 t ha^{-1}) along with gypsum (50% GR) showed higher number of spikelets spike^{-1} in BARI Gom-23 (Table 1). Salinity also caused a significant decrease in number of grains spike^{-1} of BARI Gom-23 (Table 1). Gypsum (100% GR), K_2SO_4 (200 kg ha^{-1}) and combined amendments with compost (10 t ha^{-1}) and K_2SO_4 (100 kg ha^{-1}) showed higher number of grains spike^{-1} of BARI Gom-23 than other amendments (Table 1). Salinity caused a decrease in 1000-grain weight of BARI Gom-23 (Table 1). Organic and inorganic amendments did not show a significant increase in 1000-grain weight of BARI Gom-23 under salinity conditions (Table 1).

Abou El-Magd *et al. (*2008) reported that that organic manure treatment increased all the vegetative growth parameters expressed as plant height, leaf number, fresh and dry weight of the sweet fennel under salinity conditions. Application of potash fertilizer has been shown to reduce the adverse effects of salinity in sugarcane (Idrees *et al*., 2004). Similar results were also reported by other authors (Leithy *et al*., 2010; Raafat and Thawrat, 2011).

3.2. Grain and straw yields of wheat

Soil salinity also reduced grain and straw yields of wheat (Figure 1). Inorganic amendments with sulphate of potash produced higher yield than those of other amendments. Both FYM and compost resulted in increases in grain and straw yields of wheat but there were no considerable variations in yield between FYM and compost amendments (Figure 1). Combined amendments with manures and fertilizers showed better performances.

Application of FYM alone or in combination with organic compounds increases yield of wheat as well as improves quality of wheat grain under salt stress (Raafat and Thawrat, 2011). There are also evidences that soil amendments with organic manures alleviate the toxic effects of salinity in plants (Idrees *et al*., 2004; Abou El-Magd *et al*., 2008; Leithy *et al*., 2010). Application of potash fertilizer has been reported to reduce the adverse effects of salinity in sugarcane (Idrees *et al*., 2004).

3.3. Nutrient uptake and K^+/Na^+ ratio of wheat

3.3.1. Nitrogen uptake

Salinity showed a significant decrease in straw and grain N uptake by BARI Gom-23 (Table 2). Application of gypsum (100% GR) significantly increased N uptake by straw under salinity condition. Performance of higher doses of FYM and compost was more in straw N uptake by BARI Gom-23 than that of lower doses under salinity condition. Application of K_2SO_4 (100 kg ha^{-1}) along with FYM (5 t ha^{-1}) or compost (10 t ha^{-1}) showed a higher grain N uptake by BARI Gom-23. Application of FYM (10 t ha^{-1}) performed better in grain N uptake by BARI Gom-23 than that of FYM (5 t ha^{-1}) under salinity condition. It is noted that application of compost (20 t ha^{-1}) performed better in N uptake by grain than that of compost (10 t ha^{-1}) under salinity condition.

3.3.2. Phosphorus uptake

Salinity significantly decreased P uptake by straw of BARI Gom-23 (Table 2). Application of compost (20 t ha^{-1}) significantly increased P uptake by straw in BARI Gom-23. Application of compost (20 t ha^{-1}) and K_2SO_4 (100 kg ha^{-1}) also showed similar result in wheat. Salinity significantly decreased P uptake by grain of BARI

Gom-23 (Table 2). Increased doses of FYM and compost increased P uptake by grain of BARI Gom-23 under saline conditions.

3.3.3. Sulphur uptake

Salinity caused a significant decrease in S uptake by straw of BARI Gom-23 (Table 2). Combined application of compost (10 t ha^{-1}) and gypsum (50% GR) showed a higher straw S uptake by BARI Gom-23. Under salinity condition, grain S uptake by BARI Gom-23 was significantly influenced (Table 2). Combined application of compost (10 t ha^{-1}) and gypsum (50% GR) significantly increased S uptake by grain in BARI Gom-23 under salinity condition. On the other hand, application of gypsum (100% GR) or K_2SO_4 (100 kg ha^{-1}) showed a significant increase in S uptake by grain under salinity condition.

3.3.4. K^+/Na^+ ratio

Salinity caused a significant decrease in K^+/Na^+ ratio in grain but not in straw of BARI Gom-23 (Table 3). Organic amendments with both FYM and compost significantly increased K^+/Na^+ ratio in grain of BARI Gom-23 under salinity condition. Application of K_2SO_4 showed a higher level of K^+/Na^+ in grain of BARI Gom-23 under soil salinity (Table 3). Application of organic and inorganic amendments also increased K^+/Na^+ ratio but not significantly in straw of BARI Gom-23 (Table 3).

Zaki *et al*. (2009) observed that organic manure increased NPK uptake and vegetative yield under saline conditions. Application of FYM alone or in combination with organic compounds increases yield of wheat as well as improves the nutritional status of wheat grain under salt stress (Raafat and Thawrat, 2011). Abou El-Magd *et al.* (2008) reported that organic manure treatment increased all the vegetative growth, green yield, nutrient contents (N, P and K) and K/Na ratio. Leithy *et al*. (2010) found that organic amendments did not show any changes of nutrient content except Na.

3.3.5. Changes in post-harvest soil properties

We investigated the changes in soil properties such as pH, EC, exchangeable Na and organic matter status. No remarkable changes in soil properties were observed by addition of manures and fertilizers to the saline soils (data not shown).

Table 1. Effects of organic and inorganic amendments on growth and yield components of BARI Gom-23 under soil salinity.

Treatments	Plant height (cm)	Spike length (cm)	Number of spikelets $spike^{-1}$	Number of grains $spike^{-1}$	1000-grain wt (g)
T_1: Control	78.40b	8.85b	14b	34e	43.56
T_2: FYM (5 t/ha)	82.20a	9.80ab	16ab	42bcd	44.92
T_3: FYM (10 t/ha)	83.40 a	9.86ab	16ab	42bcd	45.56
T_4: Compost (10 t/ha)	83.80a	10.26ab	16ab	40cd	44.44
T_5: Compost (20 t/ha)	84.20 a	10.00ab	16ab	42bcd	44.68
T_6: Gypsum (50% GR)	84.60a	9.90ab	16ab	42bcd	45.08
T_7: Gypsum (100% GR)	85.20 a	10.03ab	16ab	44a	44.02
T_8: K_2SO_4 (100 kg/ha)	84.20a	9.86ab	16ab	39d	45.48
T_9: K_2SO_4 (200 kg/ha)	84.80a	10.13ab	16ab	44a	45.96
T_{10}: FYM (5 t/ha) + gypsum (50% GR)	82.30a	10.56ab	17a	42abc	44.18
T_{11}: FYM (5 t/ha) + K_2SO_4 (100 kg/ha)	82.30a	11.15a	17a	43ab	45.04
T_{12}: Compost (10 t/ha) + gypsum (50% GR)	84.80a	9.95ab	16ab	41bcd	45.72
T_{13}: Compost (10 t/ha) + K_2SO_4 (100 kg/ha)	84.40a	10.13ab	16ab	44a	45.96
SE (±)	1.42	0.52	0.44	0.90	NS
CV (%)	2.46	8.41	5.91	6.73	2.61

Same letter in a column represents insignificant difference at $p < 0.05$

NS= Non significant

SE= Standard errors of means

CV=Co-efficient of variation

Table 2. Effects of organic and inorganic amendments on nutrient uptake by BARI Gom-23 under salinity condition.

Treatments	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		S uptake (kg ha^{-1})	
	Straw	Grain	Straw	Grain	Straw	Grain
T_1: Control	17.20h	30.69d	1.82e	2.43h	7.08i	6.50d
T_2: FYM (5 t/ha)	25.42bcde	41.40bc	2.33bc	3.37f	10.44ef	6.18bcd
T_3: FYM (10 t/ha)	28.57a	44.18abc	2.49abc	3.57e	11.25bc	6.32a-d
T_4: Compost (10 t/ha)	27.51abc	39.56cd	2.39bc	3.09g	11.31b	5.57cd
T_5: Compost (20 t/ha)	28.13ab	47.58abc	2.66a	3.77d	10.71de	6.68a-d
T_6: Gypsum (50% GR)	22.82efg	45.22abc	2.41bc	3.84bcd	10.91cd	6.87a-d
T_7: Gypsum (100% GR)	29.48a	48.00abc	2.50ab	4.05b	10.18fg	7.32abc
T_8: K_2SO_4 (100 kg/ha)	21.29g	47.86abc	2.30bcd	4.01bc	11.24bc	7.52abc
T_9: K_2SO_4 (200 kg/ha)	22.25fg	52.14ab	2.08d	5.50a	11.16bc	8.71a
T_{10}: FYM (5 t/ha) + gypsum (50% GR)	21.96fg	47.60abc	2.29bcd	3.89bcd	9.64hi	7.50abc
T_{11}: FYM (5 t/ha) + K_2SO_4 (100 kg/ha)	23.40def	54.18a	2.24cd	4.20a	10.16fg	8.58ab
T_{12}: Compost (10 t/ha) + gypsum (50% GR)	25.07cde	47.00abc	2.37bc	3.81cd	11.95a	7.65abc
T_{13}: Compost (10 t/ha) + K_2SO_4 (100 kg/ha)	27.04abcd	53.72a	2.32bcd	4.80a	9.88gh	8.46ab
SE (±)	2.08	1.37	0.02	0.01	0.04	1.28
CV (%)	17.8	16.91	9.86	15.29	11.35	22.16

NS= Non significant
Same letter in a column represents insignificant difference at $p < 0.05$.
SE= Standard errors of means
CV=Co-efficient of variation

Table 3. K^+/Na^+ ratio in wheat influenced by organic and inorganic amendments under salinity condition.

Treatments	K^+/Na^+ (in straw)	K^+/Na^+ (in grain)
T_1: Control	9.26	13.60c
T_2: FYM (5 t/ha)	11.11	15.35bc
T_3: FYM (10 t/ha)	10.78	15.43bc
T_4: Compost (10 t/ha)	10.79	15.48bc
T_5: Compost (20 t/ha)	11.11	16.84ab
T_6: Gypsum (50% GR)	15.66	15.52bc
T_7: Gypsum (100% GR)	13.92	15.98abc
T_8: K_2SO_4 (100 kg/ha)	15.66	18.02ab
T_9: K_2SO_4 (200 kg/ha)	13.84	18.73a
T_{10}: FYM (5 t/ha) + gypsum (50% GR)	12.04	16.36ab
T_{11}: FYM (5 t/ha) + K_2SO_4 (100 kg/ha)	12.67	16.50ab
T_{12}: Compost (10 t/ha) + gypsum (50% GR)	12.04	17.53ab
T_{13}: Compost (10 t/ha) + K_2SO_4 (100 kg/ha)	12.88	17.32ab
SE (±)	0.59	0.906
CV (%)	16.82	9.74

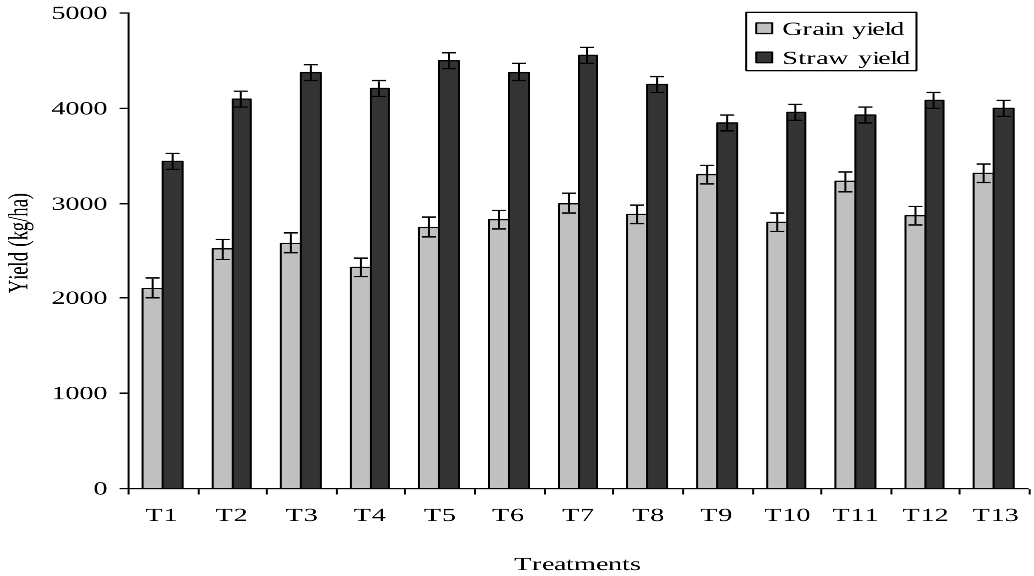

Figure 1. Effects of organic and inorganic amendments on grain and straw yields of wheat.

4. Conclusions

Organic and inorganic amendments viz. FYM, compost, gypsum and sulphate of potash reduced the adverse effects of soil salinity and increased the growth and yield of wheat. Both organic and inorganic amendments under study increased nutrient uptake and K^+/Na^+ ratio in wheat during soil salinity. Sustainable crop production is feasible in saline areas if soils are properly reclaimed with organic manures and fertilizers.

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Conflict of interest

None to declare.

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